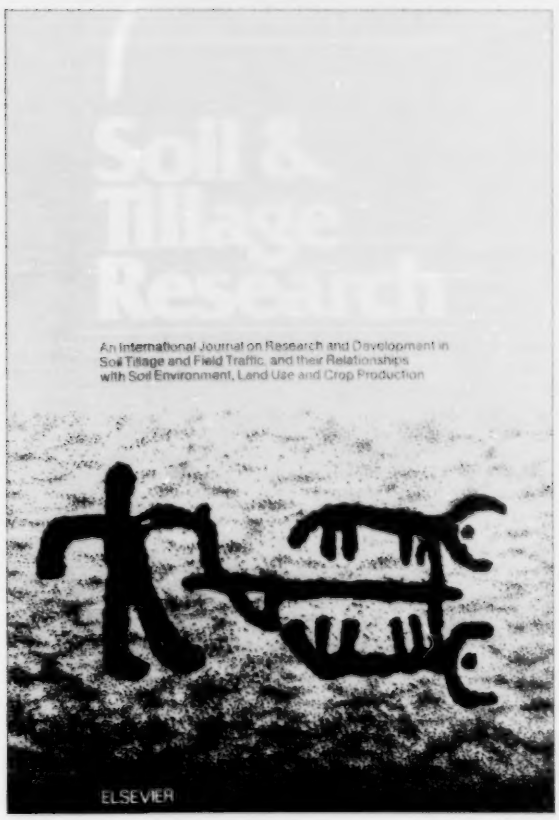
REPRINTED FROM:


Soil & Tillage Research
An International Journal on Research and Development in Soil Tillage and Field Traffic, and their Relationships with Soil Environment, Land Use and Crop Production
ELSEVIER

ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM

88-01325/

Soil & Tillage Research

An International Journal on Research and Development in Soil Tillage and Field Traffic, and their Relationships with Soil Environment, Land Use and Crop Production

Editors-in-Chief
A. Hadas
A.R.O. Div. of Soils and Water
The Volcani Center
P.O. Box 6
BET DAGAN, 50-200, Israel

W.B. Voorhees
U.S. Dept of Agriculture
A.R. North Carolina Region
North Central Soil Conservation Research Lab.
MORRIS, MN 56267, U.S.A.

Published in Collaboration with the
International Soil Tillage Research
Organization (ISTRO)

Editorial Advisory Board

Chairman
W.E. Larson,St. Paul, MN, U.S.A.

R.R. Allmaras, Pendleton, OR, U.S.A.
A. Canarache, Bucharest, Romania
R.Q. Cannell, Wantage, Great Britain
G. Chisci, Florence, Italy
W. Ehlers, Göttingen, F.R.G.
M. Estler, Freising-Weihenstephan, F.R.G.
E.L. Greacen, Glen Osmond, S.A., Australia
L. Henriksson, Uppsala, Sweden
J. Kampen, New Delhi, India
G. Keçecioğlu, Bornova-Izmir, Turkey
J.W. Ketcheson, Guelph, Ont., Canada
H. Kuipers, Wageningen, The Netherlands
R. Lal, Ibadan, Nigeria
J. Luis Hernanz, Madrid, Spain
A. Maillard, Nyon, Switzerland
J.V. Mannering, West Lafayette, IN, U.S.A.
E. McKyes, Ste. Anne de Bellevue, Que., Canada
V. Mihalić, Zagreb, Yugoslavia
G. Muchiri, Nairobi, Kenya
O. Muzilli, Londrina, PR, Brazil
D.R. Nielsen, Davis, CA, U.S.A.
A. Njøs, As-NLH, Norway
B.S. Pathak, Ludhiana, India
J. Sakai, Hakozaki, Higashi-ku, Fukuoka, Japan
R.L. Schafer, Auburn, AL, U.S.A.
J. Šimon, Prague, Czechoslovakia
R.E.H. Sims, Palmerston North, New Zealand
B.D. Soane, Penicuik, Midlothian, Great Britain
H.M. Taylor, Ames, IA, U.S.A.
C. van Ouwerkerk, Haren, The Netherlands

Soil & Tillage Research, 10 (1987) 55–65
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

Pedotechnology and Tillage Research

G. WILSON

Agriculture Canada, Land Resource Research Centre, Ottawa, Ont. K1A 0C6 (Canada)

(Accepted for publication 18 May 1987)

ABSTRACT

Wilson, G., 1987. Pedotechnology and tillage research. *Soil Tillage Res.*, 10: 55–65.

This paper summarizes a compactibility interpretation symposium – the first efforts of ISSS Working Group PT (Pedotechnique) to improve geotechnical engineering interpretations of existing soil survey data bases. Proposed interpretation schemes and alternative approaches are discussed.

These efforts have also resulted in the identification of 3 avenues of needed research, specifically for tillage soil scientists, and the discussion is presented. The first need is formal recognition of soil mechanical factors and development of improved soil science data bases for tillage, the second is for compatible methods of interpretation and the third is for better documentation of the areal extent of tillage problems through improved soil tillage inventories. It is shown that these 3 avenues of tillage study could be organized within the proposed new ISTRO structure through a committee on Pedotechnology.

INTRODUCTION

Considerable progress has been made in recent years in illustrating the potential impact of soil problems by reference to maps showing the geographical distribution of soils. Examples given (USDA, 1971) are intended specifically for the interpretation of existing soil survey data bases and for use with engineering soil problems. In addition, engineers have suggested that users of the surveys should first be provided with a better understanding (or interpretation) of mapping concepts used in soil survey, before attempting to assess the relevance of data bases for soil engineering problems (Kvarv, 1982). Analogous methods have subsequently been proposed (Wilson, 1982a), and the need for positive links between disciplines recognized (Wilson and van Ouwerkerk, 1987). In addition, most previous efforts have been expended on linking soil surveys with civil or geotechnical engineering. Evidence is lacking to show that similar efforts have been applied to agricultural engineering, tillage and trafficability on the land.

To fill this apparent gap the ISSS Working Group PT was established, and

0167-1987/87/$03.50 © 1987 Elsevier Science Publishers B.V.

interested soil scientists prepared a symposium for the 1986 Hamburg Congress. One specific topic, the rating of agricultural soils for compactibility, was selected as a suitable example with which to start.

The objective of this paper is to summarize, in a general way, the combined efforts of this group activity by demonstrating its possible significance to researchers in soil tillage through special avenues of tillage research work which have been identified.

MATERIALS AND METHOD

The relevance in soil tillage research of the following are examined:
(a) geographic aspects of tillage soil problems;
(b) disciplines involved in documentation of tillage problems;
(c) examples of approaches taken;
  (1) data bases;
  (2) interpretation;
  (3) inventory;
(d) pedotechnology in ISTRO.

Research material is mainly from references in the literature and in particular the symposium papers. Little original data is used.

RESULTS AND DISCUSSION

(a) Geographical aspects of tillage research

The role of geography in environmental problems is well documented, and also, more recently, in relation to the general problem of soil degradation (Sparrow, 1984). A fact emphasized by Senator Sparrow (Canada Senate Committee on Agriculture) is that many farmers are already aware of soil degradation problems, but most do not realise the extent to which the nation's productive land is threatened by it. He did not realise this himself, until in 1982 he was given a guided tour of affected areas in Saskatchewan. The report of the Senate Committee on Agriculture emphasized that the full extent of soil degradation problems, like compaction, are definitely not well documented in Canada.

Similar conclusions were drawn and reported in the "85 Outlook" for Canadian agricultural land and water resources (Agriculture Canada, 1985). The awareness aspect of the problem was repeatedly stated. It was understood that progress would depend on an improved flow of information, but that techniques used would have to be tailored to the soils.

For centrally planned economies, Canarache (1987) has shown the special interests which exist for land classifications for various tillage systems. Most of these have been developed in the past 5 years.

McCormack states (McCormack, 1987) that soils most susceptible to com-

paction must be identified and that, because many such soils are vitally important for food production, methods of cultivation must be found that will avoid over-compaction.

In addition, agricultural engineers question the lack of suitable information on soil parameters (Voisey, 1986). While individual farmers may known where some of their soil compaction problems are (Sparrow, 1984), the overall problem is not well documented. It can also be said that while individual farmers know the "farming" properties of most of their soils, and while certain soil tillage scientists may have well documented records of individual soils they have studied, the tillage properties of soils in general are not well documented. The Soils of Canada (Clayton et al., 1977) is a prestigious publication, containing a report and inventory of Canada's land and soils. It is a comprehensive coverage of the pedology, but "state of the art" tillage parameters are not included.On the other hand, in publications such as ISTRO, "state of the art" tillage parameters of the individual soils described are frequently given. Agricultural engineers, among others, have need to refer to tillage parameters if they are to "tailor" soil amelioration, or other corrective systems, to the soil correctly. But, perhaps with the exception of countries like Romania, tillage parameters for guidance in design are rarely available, in suitable form, in the national inventories.

(b) Disciplines involved in documentation of tillage problems

In most existing approaches to land evaluation (McCormack, 1987), soil compaction has been ignored. It is admitted that, with increased use of heavy machinery in crop production, more attention must be given to compaction, and that soils most susceptible to it must be identified. Soil surveyors are by and large failing to note the presence of compacted layers, although in Indiana comprehensive interpretations have been developed for selected tillage systems. McCormack suggests that a new set of terms is needed, and also training for soil surveyors in this line of work.

Canarache (1987) suggests that, in Romania, general coverage of tillage-related soil problems is made easier owing to available soil maps and computer data storage. Processing of this data is said not to be a difficult problem. It might be inferred that, since the geographical distribution of the main soils has been or is being accomplished, it remains for detailed tillage parameters and other characterizations to be added.

A National Agricultural Land Use study identified soil compaction as one of the leading causes of soil degradation threatening future productivity of American farm land (Voorhees, 1987). Voorhees shows that, owing to a unique combination of soil–climate–cultural practices, some regions of the United States have clearly defined compaction problems; but that in the majority of the U.S. the consequences of soil compaction are not so clearly defined and quantified.

Yield increases with moderate compaction and the special effects of soil structure, among other factors, are quoted. Basically, 3 steps are involved in one approach being taken by soil scientists in the United States. These comprise assessment of soil compactibility, compaction probability and the agro-economic response. It is, for example, noted that, in the assessment of compactibility, agricultural engineering machinery characteristics, wheel configuration and soil/tire contact pressures are considered. Koolen (1987) expands further on this theme by showing the effects that the initial soil condition has on the nature and extent of the soil pressures generated by different types of wheels and wheel configurations.

In texts such as Soil Dynamics in Tillage and Traction (Gill and Vander Berg, 1968) reference is made to the findings discussed in research contributions on agricultural soil compaction prior to 1950. In the 60's, off-road machines and their sinkage in soils had been investigated, and factors contributing to compaction described. The evidence appears to indicate that the effects of compaction on soil strength, seedling emergence, soil temperature, soil aeration and self-ameliorating processes have previously been quite well described. Poor documentation of the problems (Sparrow, 1984), may have resulted because existing geographical data bases do not adequately incorporate these findings.

The 1986 ISSS (PT) Compactibility Interpretation Symposium was consequently planned for the flow of "state of the art" information from tillage soil scientists to soil surveyors. But if, as Canarache shows, the location of boundaries of different soils are already mapped or are in process of being mapped, tillage scientists are in a better position to use these boundaries to document tillage characteristics and potential tillage problem areas. Tillage specialists could take a greater interest in inventorying tillage properties of soils, and in assuring better future documentation of these national and global problems.

(c) Examples of approaches taken

The first approach, attempted by the ISSS working group (PT), was to investigate the interpretation of existing soil survey data bases for compactibility of agricultural soils in order to be able to recommend a standard method for interpreting soil surveys. Although specific but quite different working schemes were described (Canarache, 1987; Voorhees, 1987), a standard method could not be recommended. It was evident that there was no standard soil science approach, but that there was concensus that a comprehensive soil science tillage data base would be required. Koolen (1987) also suggested that much more basic research would be required, and that to attempt to standardize with existing material would, indeed, be a challenge to the "engineering approach". While the business of engineering may be to interpret, it is neither intended to specify a soil science tillage data base nor to identify critical values.

STILL 101 katern 4

Before pursuing this particular "tillage compaction geography" objective further it should now be apparent that further consultation with tillage researchers is needed. Consultation is required to cover 3 main aspects of this type of work; (1) data bases; (2) methods of interpretation; (3) inventories. For the data bases, one of the objectives should be the setting down of all relevant tillage parameters for the present "state of the art" in an acceptable format. Methods of interpretation should be investigated to show the approximate response of the soil to mechanical and other equipment. The method of interpretation must be compatible with the data base, and must apply to the various seasons and times of the year. By adding geographical boundaries better awareness of the severity of, and area affected by, tillage problems should result. A start could be made to inventory one or two well known soils in different parts of the world. These would give a global perspective, and could be followed by specific inventories of localized areas on a national scale. The challenge (Koolen, 1987) is redirected; it is for tillage scientists to extrapolate findings from specific experimental sites to cover national geographic areas.

(1) Data bases

The special requirements of a soil data base for tillage have been adequately defined by the following statement (W. Reid, 1987, personal communication): "As an agricultural engineer and having farmed and worked various types of land, I have yet to properly recognize the special "personalities" of these lands from any soil inventory I have ever consulted."

Examples of fundamental types of study required when considering the application of engineering soil mechanics parameters relevant for use in tillage soil data bases are given (Koolen, 1987). MacCormack (1987) lists other in-situ factors (presence of organics, etc.) to be considered as influencing the effects of mechanical stress on soil compactibility.

Another possible approach, initially developed for geotechnical engineering applications (Wilson, 1982b), was to exhibit a special interpretation of the soil survey data base in the form of a setting sheet, illustrating the most central concept of the mapping unit. Following that approach, locally well-known soils might be listed for tillage purposes and "first order" characterization provided. The characterization may be set out as shown in Fig. 1, which is intended to present selected examples rather than to be a completed document.

The soil mechanics response of named soils is not only the response of separate particles of the soil, but the aggregate response of all the soil bodies existing on that type of landscape under the climatic and vegetation conditions prevailing. This inter-relationship is demonstrated by Heading No. 1, "Landscape Parameters", and a number of possible settings are illustrated.

While soil mechanics characteristics might be expected to be found only under the heading Soil Physical Parameters, this is not necessarily so. Soil mineralogy and soil chemistry can also strongly influence engineering per-

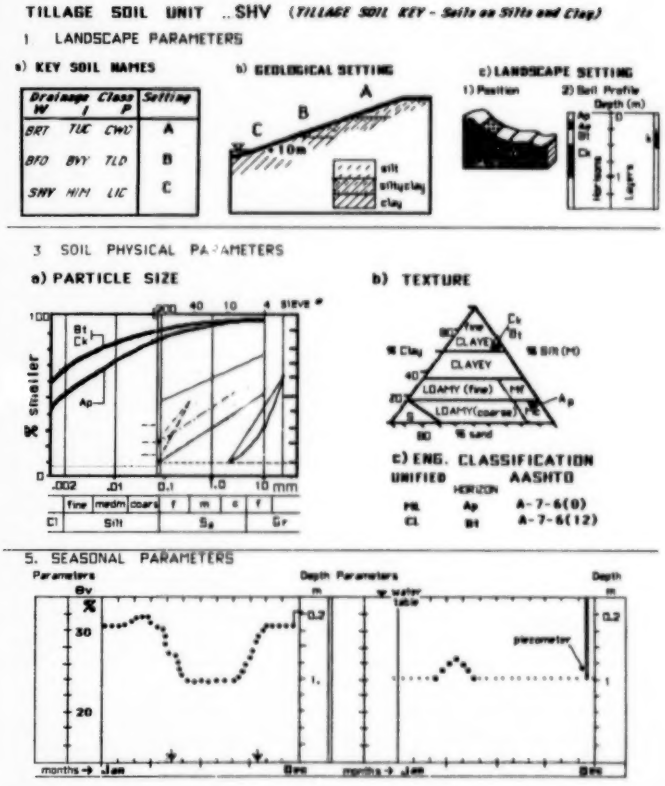


Fig. 1. Parameters for Tillage Soil Unit - SHV.

formance. "Soil Physical Parameters" are listed as Heading No. 3, to emphasize this point. Particle size relationships of the Ap, Bt and Ck horizons are shown on 3(a).

Named soils will also have parameters which vary throughout the year. These are indicated on Fig. 1 by the heading "Seasonal Parameters". The first module under this heading indicates the volumetric moisture content θv and the second refers to the water table. Depth is shown on the right of each module e.g. θv is for the Ap horizon at a depth of 0.2 m. The data was obtained from a probability determination based on climatic records (Dyer and Murray, 1985).

Standardized methods have not been established for illustrating a soil tillage data base, but some combination of methods shown, plus other proposals awaited, may eventually contribute towards a suitable standard.

(2) Interpretation

The papers by Voorhees (1987) and Canarache (1987) adequately describe specific interpretation or classification schemes which contain input from til-

lage scientists, and which have already been in use or are presently contemplated. The following additional examples are offered:

(i) Pedotechnical example. Interpretations of the data base shown on Fig. 1, 3(a) are illustrated on modules 3(b) and 3(c). 3(b) gives the textural name based on the proportions of clay-sized particles, and 3(c) is the engineering classification based on the particle size relationships plus other index parameters (not shown). The particle size relationships can be determined directly on module 3(a) by comparing the forms of the particle size curves with the indicators (unnamed lines), as described in Wilson (1983). The two engineering classifications UNIFIED and AASHTO have different objectives. The UNIFIED classification indicates differences in types of performance without rating any specific quality; the AASHTO rates soils according to their quality for one specific purpose, quality as a base course for highway construction.

To add to the graphic definition of the SHV soil unit, the seasonal variation of the θv parameter may be further interpreted to indicate probability dates for limiting trafficability conditions on the land owing to excess moisture. The arrows indicate likely earliest and latest dates for getting on and off the land (Wilson, 1985).

(ii) Problem analysis. Problem analysis permits specific aspects of agricultural soil compaction to be identified. From this an ad hoc interpretation scheme (Wilson, 1986), might be developed for immediate application. A trend toward increase of tractor size was identified as early as 1968 (Gill and Vander Berg, 1968). This was examined with recent data (I & T Redbook, 1983). The results confirmed that this trend persisted until 1983. As faster operations are still likely to equate with better economics, the trend is likely to continue. The trend was extrapolated and a compactibility scheme "design tractor" of 25 t (2000 AD) was obtained (Wilson, 1986).

(iii) Soil compaction stresses. Existing relationships developed over the years for matching tyres and plough layer ground contact pressures (termed flotation) are not likely to change. Continued increase in tractor size will be equated with increase in contact area. As most economical arrangements for increasing contact area are wider tyres or close spaced multiples, stresses due to tractors of this size could extend to depths equivalent to this combined tyre width (Koolen, 1987).

(iv) Specified type of compaction. As the imposed stresses could extend beyond the influence of self ameliorating effects (frost action, etc.) and beyond the depth of amelioration due to "normal" tillage, the net result of the problem analysis is a more specifically directed scheme, with less factors involved. A workable "deep, machine-induced compactibility" scheme could be based on ratios of soil physical parameters.

(v) Quantification. If, for example, ratios of the parameters for land tilled with light machines compared to the same land subject to the specified design loading could be obtained, methods of rating this aspect of compactibility could

be achieved. Degree of compaction is presently expressed by bulk density ratios (Canarache, 1987). An interpretation chart, compatible with the data base, could be compiled (Wilson, 1986). This could show, for any specific soil, the effects of the design compaction loading on a group of interrelated parameters as well as bulk density ratio; for instance porosity, permeability and strength. Ratios for known soils could also be established by laboratory testing, either full scale or reduced scale, using compatible loading systems. Loads of this magnitude may not seriously affect many soils, or may even be beneficial (Voorhees, 1987). Shallow soils on bedrock, in which the extra load is taken by the strong underlying layer, are not likely to be adversely affected by increased tractor size. For soils which have been preloaded or genetically compacted (Canarche, 1987), load testing should indicate the specific contribution of machine stress to re-compactibility. If the contribution is likely to be zero, this should be emphasized.

(vi) Tying to existing systems. Taking the existing Land Capability Classification System (LCC) (McCormack, 1987), or similar schemes like the Canadian Land Inventory (Marshall et al., 1979), a land rating of say 1p signifies first class agricultural land with a minor limitation due to stoniness. Using proven ratios of these parameters, and taking into consideration relevant aspects of soil climate (Voorhees, 1987), ratings of such land could be modified to say 1pK – signifying the same soil as above, but adding the very pertinent additional limitation that this particular land would also be highly susceptible to loss of productivity from compaction induced by the introduction of heavy tillage machinery.

(3) Inventory

Tillage characteristics of many soils studied by soil scientists are on record in publications like ISTRO. The need is to inventory this type of information better, for easier practical use. Eventually, formal texts resembling The Soils of Canada (revised to include a Tillage Volume) may be published. Included would be a soils map, soils data bases, different methods of interpretation, and an inventory of the location and tillage characteristics of each named soil.

But the present need is for an expression of ideas and specific proposals on the subject, preferably as (ISTRO) papers, in which a number of well known regional soils are described and suitably illustrated in a form convenient for use by agricultural engineers, machine design specialists and also by other soil scientists interested in soil and tillage.

(d) Pedotechnology in ISTRO

In the latest issue of ISTRO-INFO (van Ouwerkerk, 1987), a questionnaire was included to reopen discussion on the proposed ISTRO Commissions and Working Groups. Among the original objectives quoted were to unite research

potential, to divide work load and to improve membership participation, under the premise that a considerable collective effort may result from individual contributions. It should be noted that this Special Issue of ISTRO is due to the collective efforts of an initially very small working group. The history of the ISSS Working Group (Wilson and van Ouwerkerk, 1987) has, to date, been more a uniting of research potential than the performance of original work. But, immediately subsequent to the 1986 ISSS Symposium, the potential contribution to research in this field received a 4-fold increase owing to new membership.

The organization of pedotechnology in tillage research could continue to be coordinated by the ISSS Working Group. Alternatively, a formal ISTRO Working Group would be more in line with the ISTRO Board proposal. However, in the report on the General Assembly decision taken to not proceed with the formation of formal Commissions (van Ouwerkerk, 1987), concerns were expressed that, because ISTRO was not yet a big enough organization, "fragmentation", "compartmentalisation" and even "fossilization" could result. In view of such previously expressed concerns, perhaps a more acceptable reorganization is a committee structure on lines similar to, for example, the U.S.A. engineering Transportation Research Board (TRB). Membership on as many different committees as possible is encouraged. The work load is shared by all committee members, and fragmentation would not be a realistic concern. A committee on pedotechnology could be one of a number of ISTRO standing committees. All ISTRO members who have joined the ISSS Working Group PT would probably be members of that committee, which should maintain liaison with ISSS because other subjects besides tillage are involved. Membership already exceeds the critical mass required to assure future growth. One or two of the many diverse ideas already generated by the group could be developed by staging a symposium, conference or poster session on the subject at the next ISTRO conference.

CONCLUSIONS

Conclusions may be listed as follows:

(1) The Symposium papers showed there was general interest in the theme, which was a search for a standard method of interpreting existing soil survey data bases for compactibility.

(2) The papers have given examples of regional schemes and factors required for special data bases to cover tillage problems like compactibility adequately. A standard scheme was not determined, but recommendations are given instead for further consultation with ISTRO membership on this subject.

(3) The working group effort has also resulted in the identification of pedotechnology as a special research need for an improved inventory of tillage characteristics of soils. The immediate objective is to assure better documentation

of environmental impact owing to soil tillage and related mechanical stress on the soil. The work is also identified as a research need, in which soil tillage scientists should assume a leading role. It should involve research to determine the most appropriate soils data base specially tailored for tillage work, methods of interpreting the data base for rating the severity of tillage problems, and inventories or easily accessible listings of known soils and their tillage characteristics.

(4) Standardized pedotechnology methods have not yet been determined. Examples of possible approaches are presented, but it is expected that, as research contributions are received, standard methods will develop in due course.

(5) Pedotechnology could be organized through an ISTRO group affiliated with ISSS Working Group PT (pedotechnique). If the request by the Board of ISTRO for establishment of a Commission structure is supported, the work could be coordinated by a working group. Alternatively, a standing committee on Pedotechnology would also be in order.

(6) The first duty of the committee would be to request sponsorship of a session at the next ISTRO conference 1988 (Scotland). As the conference theme concerns tillage and traffic, a call for papers or other presentations, on any one of the three aspects of tillage research described, could then be issued. The committee would then be performing its principal function, which is to encourage membership participation and to unite research potential for the betterment of tillage research.

REFERENCES

Agriculture Canada, 1985. Agricultural soil and water resources in Canada: situation and outlook. 85 Outlook Perspectives. Research Branch Report, 18 pp.

Canarache, A., 1987. Romanian experience with land classification related to soil tillage. Soil Tillage Res., 10: 39–54.

Clayton, J. S., Ehrlich, W. A., Cann, D. B., Day, J. H. and Marshall, I. B., 1977. Soils of Canada. Agriculture Canada, Research Branch Report, 243 pp.

Dyer, J. A. and Murray, D. R., 1985. Planting and harvesting dates in Ontario. Ontario Ministry of Food, Fact Sheet, 4 pp.

Gill, W. R. and Vander Berg, G. R., 1968. Soil dynamics in traction and tillage. USDA Agriculture Handbook No. 316, U.S. Govt. Printer's Office, Washington, DC, 468 pp.

I & T Redbook., 1983. Implement and tractor farm equipment magazine. Intertec Publishing Corp., Vol 98. No. 5, 368 pp.

Koolen, A. J., 1987. Deformation and compaction of elemental soil volumes and effects on mechanical soil properties. Soil Tillage Res., 10:5–19.

Kvarv, E., 1982. Soil factors – their relative value in road location. Min. of Environment, Research Report, 35 pp.

Marshall, I. B., Dumanski, J., Huffman, T. and Lajoie, P. G., 1979. Soils, capability and land use in the Ottawa urban fringe. Land Resource Research Institute, Research Branch Report, Agriculture Canada, 59 pp.

McCormack, D. E., 1987. Land evaluations that consider soil compaction. Soil Tillage Res., 10: 21-27.

Sparrow, Hon. H. O., 1984. Soil at risk: Canada's eroding future. The Senate of Canada, Ottawa. 129 pp.

USDA, 1971. Guide for interpreting engineering uses of soils. Soil Cons. Serv., USDA. Soils memorandum, Washington, 87 pp.

Van Ouwerkerk, C., 1987. ISTRO Commissions and working groups. ISTRO-INFO. Soil Tillage Res., 8: 377-401.

Voisey, P. W., 1986. The Canada Committee on agricultural engineering services, Research Branch Report. Agriculture Canada, 130 pp.

Voorhees, W. B., 1987. Assessment of soil susceptibility to compaction, using soil and climatic data bases. Soil Tillage Res., 10: 29-38.

Wilson, G., 1982a. Pedotechnique and its application to soil surveys - a proposal. Land Resource Research Institute Contribution No. 82-12, Research Branch Report, Agriculture Canada, 48 pp.

Wilson, G., 1982b. Pedotechnical interpretations of the soils of the Ottawa urban fringe. Land Resource Research Institute Contribution No. 82-37, Research Branch Report, Agriculture Canada, 34 pp.

Wilson, G., 1983. Interpretation sheets for engineering classifications in soil surveys. Can. J. Soil Sci., 63: 679-689.

Wilson, G., 1985. Haldimand-Norfolk Soil Survey: Pedotechnical Interpretations. Land Research Resource Institute Contribution No. 84-57, Research Branch Report, Agriculture Canada, 31 pp.

Wilson, G., 1986. Report of activities; working group PT: Trans. 13th Congress of ISSS, Vol. IV, pp. 1628-1636.

Wilson, G. and van Ouwerkerk, C., 1987. Pedotechnique, the link between pedology and engineering. Soil Tillage Res., 10: 1-3.

GENERAL INFORMATION

Aims and scope. This journal is concerned with the changes in the physical, chemical and biological parameters of the soil environment brought about by soil tillage and field traffic, their effects on crop establishment, root development and plant growth, and their interactions. This implies research on selection, adaption or development of tillage systems (including reduced cultivation and direct drilling) suitable for specific conditions of soil, climate, relief, irrigation and drainage, crops and crop rotations, level of fertilization, degree of mechanization, etc. In this context papers on development of soil working tools and traction devices, energy requirements and economic aspects of tillage are most welcome. The same holds for research on soil-deformation processes, measuring methods and mathematical modelling in connection with the soil-machine-plant system. Special attention will be given to the role of tillage in weed, pest and disease control.

Publication schedule. Soil & Tillage Research comprises four issues per annual volume of approx. 400 pages. 1985, Volumes 5 and 6.

Subscriptions. Subscription price for Volumes 5 and 6 is Dfl. 394.00 (approx. US $146.00) including postage and handling. Send your order to your usual supplier or direct to Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands.

Submission of articles. Manuscripts should be submitted in triplicate to the Editorial Secretariat "Soil & Tillage Research", P.O. Box 330, 1000 AH Amsterdam, The Netherlands.

Note to Contributors

Types of papers published in the journal
– papers reporting results of original research – review articles – short communications – (guest) editorials – book reviews – ISTRO-INFO – reading table.

A detailed *Guide for Authors* is available upon request and is also printed in the first issue of each volume. You are kindly asked to cunsult this guide. Please pay special attention to the following notes:

Language
The official language of the journal is English.

Preparation of the text
(a) The manuscript should include at the beginning an abstract of not more than 200 words.
(b) It should be typewritten with double spacing and wide margins. Words to be printed in italics should be underlined. The metric system should be used throughout.
(c) The title page should include: the title, the name(s) of the author(s) and their affiliation(s).

References
(a) References in the text should be cited as the name of the author(s), followed by the year of publication.
(b) The reference list should be in alphabetical order and on sheets separate from the text.

Tables
Tables should be compiled on separate sheets. A title should be provided for each table and all tables should be referred to in the text.

Illustrations
(a) All illustrations should be numbered consecutively and referred to in the text.
(b) Drawings should be completely lettered, the size of the lettering being appropriate to that of the drawings, but taking into account the possible need for reduction in size (preferably not more than 50%). The page format of the journal should be considered in designing drawings.
(c) Photographs must be of good quality, printed on glossy paper.
(d) Figure captions should be supplied on a separate sheet.

Proofs
One set of proofs will be sent to the author to be checked for printer's errors. In the case of two or more authors please indicate to whom the proofs should be sent.

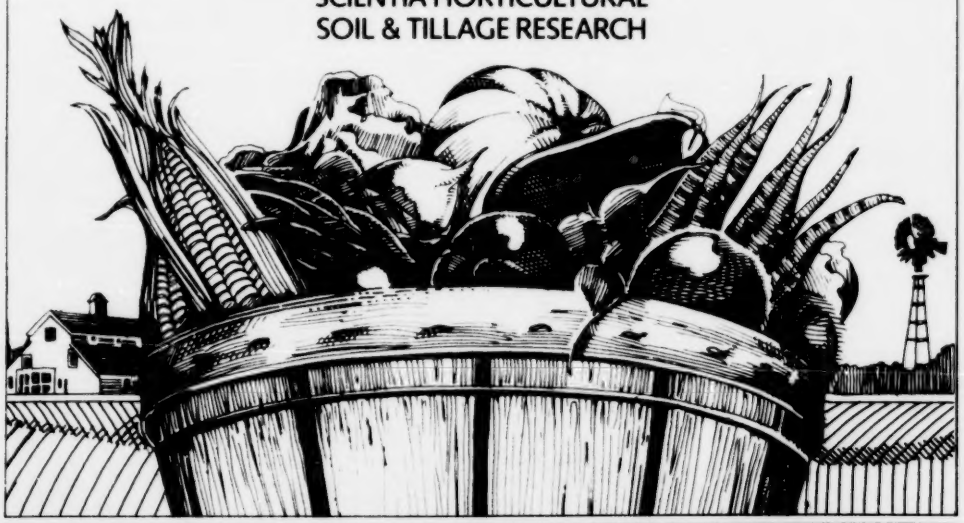
Reprints and page charges
There is no page charge. Fifty reprints of each article published will be supplied free of charge. Additional reprints can be ordered on a reprint order form which is included with the proofs.

All contributions will be carefully refereed for international relevance and quality. Submission of an article is understood to imply that the article is original and unpublished and is not being considered for publication elsewhere.

SOIL & TILLAGE RESEARCH HAS NO PAGE CHARGES
A FREE SAMPLE COPY OF THE JOURNAL IS AVAILABLE ON REQUEST

AGRICULTURAL RESEARCH JOURNALS FROM ELSEVIER

AGRICULTURAL AND FOREST METEOROLOGY
AGRICULTURAL WATER MANAGEMENT
AGRICULTURE, ECOSYSTEMS & ENVIRONMENT
ENERGY IN AGRICULTURE
FIELD CROPS RESEARCH
FOREST ECOLOGY AND MANAGEMENT
PROTECTION ECOLOGY
SCIENTIA HORTICULTURAE
SOIL & TILLAGE RESEARCH



For further details contact : **ELSEVIER SCIENCE PUBLISHERS**
P.O. Box 330 - 1000 AH Amsterdam - The Netherlands